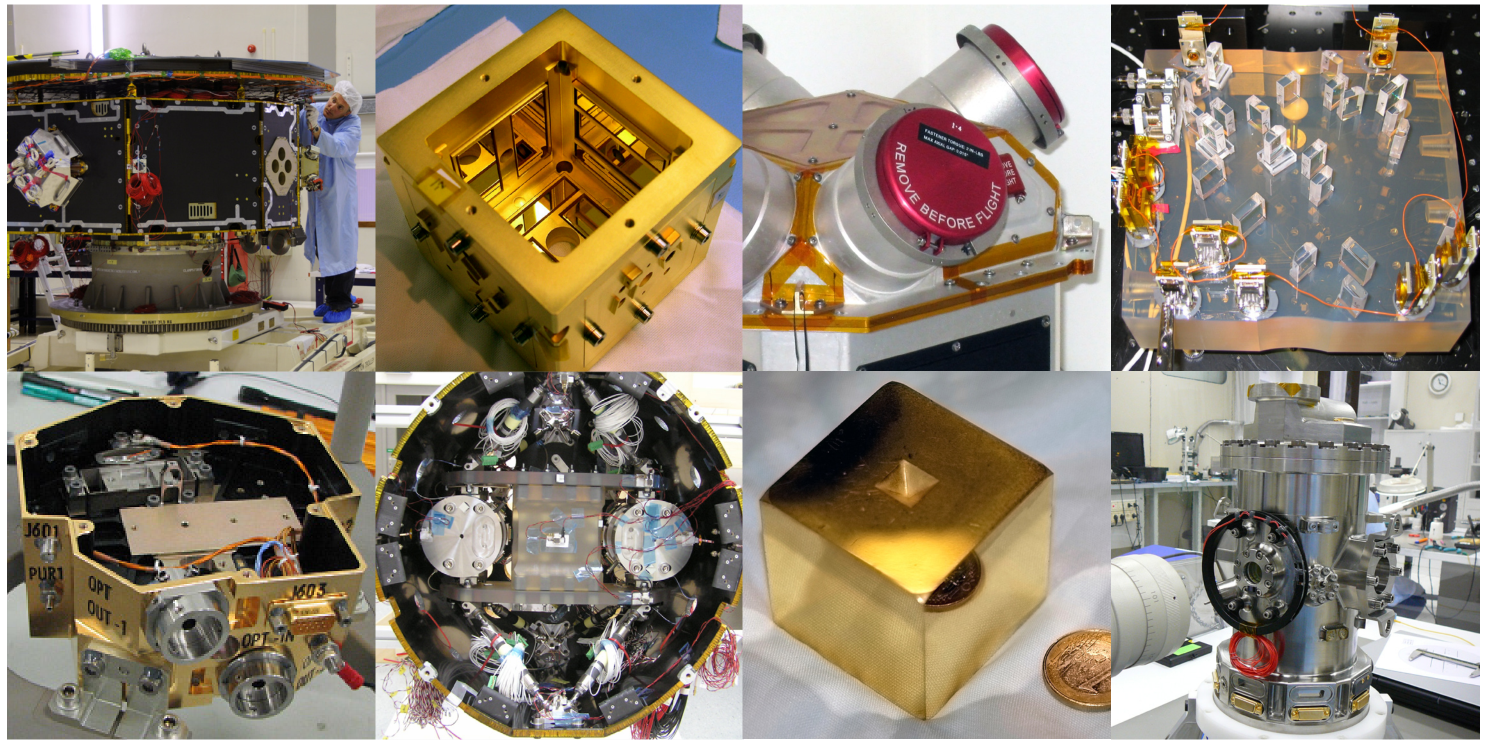


LISA Pathfinder, an ESA mission to validate the LISA drag-free operation, shares many crucial components of the LISA flight hardware.

From the top left, clockwise: side view of LISA Pathfinder sciencecraft (Astrium/ESA), test-mass housing (Thales Alenia Space/INFN), colloid thruster (Busek/JPL), optical bench (University of Glasgow/STFC), vacuum enclosure (Carlo Gavazzi Space), platinum–gold test mass (Thales Alenia Space/ASI), payload qualification model (Astrium/ESA), acousto-optic modulator (Oerlikon Space/CNES).

Quick facts for LISA, a joint NASA–ESA mission to detect gravitational waves

Frequency range:	0.03 mHz–0.1 Hz
Measurement concept:	laser metrology between six fiducial masses on three spacecraft
Mission	
Orbits:	independent heliocentric orbits, trailing Earth by 20 degrees
Formation:	triangular with 5-million-km arms, passively maintained
Spacecraft:	short cylinder, 2.9 m diam x 0.93 m high, 643 kg, 794 W
Attitude/station-keeping:	drag-free control of spacecraft
Thrusters:	three clusters of four, 30 μN maximum thrust
Technology demonstration:	LISA Pathfinder/ST-7 (ESA/NASA, launch 2012) will validate drag-free spacecraft operation
Payload (on each spacecraft)	
Lasers:	two 1-W diode-pumped 1064-nm Nd:YAG oscillators + amplifiers
Test masses:	two 2-kg Au–Pt cubical masses, 46 mm wide
Telescopes:	two 40-cm diameter, used both to transmit and receive
Science	
Data volume:	approximately 60 GB over 5 years
Sources:	compact Galactic binaries, massive black hole binaries, extreme–mass-ratio inspirals, stochastic backgrounds, bursts
Source localization:	typically arcminutes to one degree

On the Web

For the public
lisa.nasa.gov
lisa.esa.int

For scientists
www.lisascience.org
list.caltech.edu

Image credits for pages 1–3: NASA/ESA/Hubble Heritage Team (cover); Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam, Germany and Milde Science Communication (LISA animation stills); S. Phinney (mass-transferring Galactic binary); Caltech/Cornell numerical-relativity group (black-hole binary simulation); R. Battye & E. P. Shellard (string simulation); A. M. Srivastava (liquid crystals).

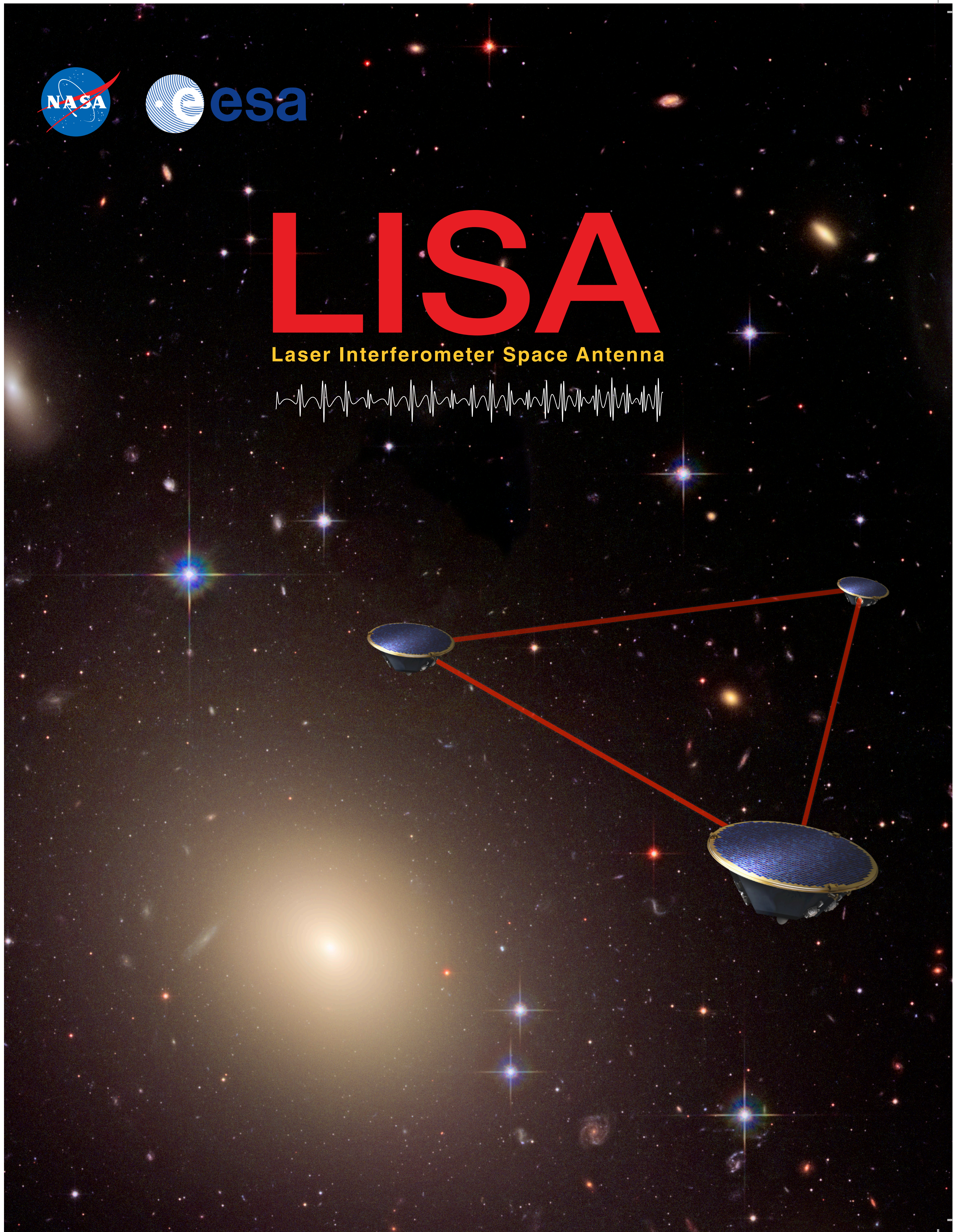
The U.S. LISA Project is managed by Goddard Space Flight Center with participation by the Jet Propulsion Laboratory.

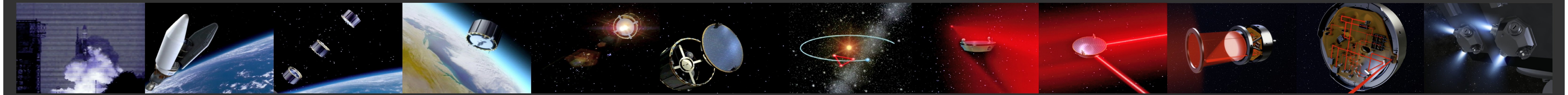
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

JPL 400-1369, Rev. 1 12/09





Watch an animation of LISA at www.lisa.aei-hannover.de: the three spacecraft are launched together and cruise to a solar orbit, where they settle into a 5-million-km triangle. LISA measures gravitational waves by using laser interferometry to monitor the distance fluctuations between freely-falling reference masses. Exquisitely precise thrusters keep the spacecraft hovering around the masses, protecting them from external disturbances.

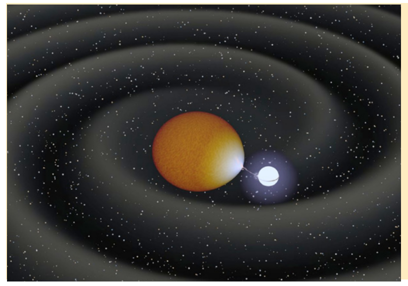
Gravity is talking.
LISA will listen.

"LISA is an extraordinarily original and technically bold mission concept. LISA will open up an entirely new way of observing the Universe, with immense potential to enlarge our understanding of physics and astronomy in unforeseen ways."

National Academy of Sciences
NASA's Beyond Einstein Program: An Architecture for Implementation (2007)

Einstein's general relativity predicts that accelerated masses produce **gravitational waves**, perturbations of spacetime that propagate at the speed of light and are virtually undisturbed by intervening mass. Their measurement will add a new sense to our perception of the Universe, providing rich, unique information about its behavior, structure, and history.

The **joint NASA–ESA space mission LISA** will measure gravitational waves of frequency between 0.03 mHz and 0.1 Hz, a band inhabited by a **wide range of sources**, such as massive black holes merging at the centers of distant galaxies; the inspirals of compact objects into central black holes; binaries of compact stars in our Galaxy, and beyond; and, possibly, gravitational-wave relics from an extremely short time after the Big Bang.



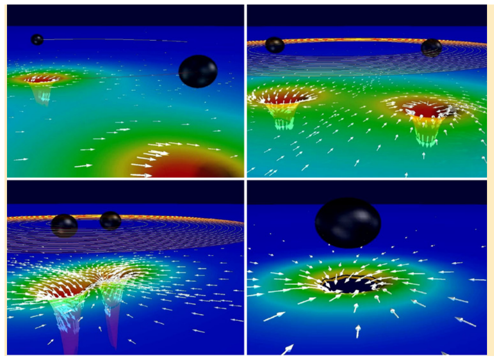
LISA will study thousands of compact binaries and their place in the Galaxy

It will compile a catalog of several thousand individual systems; it will measure distances and accurate orbit and mass parameters for hundreds of short-period systems

The dominant gravitational-wave contribution in the LISA band comes from **short-period binaries of compact stellar objects** (white dwarfs, neutron stars, black holes, and naked He stars), predominantly from the millions of such systems in our Galaxy, but also from farther afield.

The accumulated signal from a few known **verification binaries** will stand out in the LISA data a few months after commissioning, and will provide the first validation that LISA is operating correctly. In addition, LISA will individually observe **several thousand unknown binaries**, those closest to us or with frequencies above 3 mHz (i.e., orbital periods shorter than 10 minutes). All other systems will blend into a confusion-limited foreground that LISA will characterize statistically.

This **Galactic census** will give us unprecedented insight into the evolution of close binary systems and of the progenitors of some types of supernovae, neutron stars, and black holes. It will also provide rich information about tidal interactions and other non-gravitational effects that are associated with the internal physics of the stellar remnants.



LISA will record the inspirals and mergers of binary black holes throughout the Universe

It will observe tens to hundreds of coalescing 10^4–10^7 $M_\odot$ black-hole binaries, measuring masses to 0.1–10%, sky positions to few degrees, and luminosity distances to 1–10%

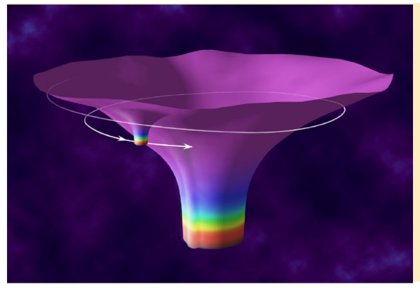
Most galactic centers are thought to harbor supermassive black holes—and as host galaxies merge, so do their nuclear black holes.

LISA will be sensitive to gravitational waves from the coalescences of black-hole binaries with total mass between 10^4 and 10^7 $M_\odot$ (solar masses), out to $z \sim 20$. It will record waves from the final phase (months to years) of their gravitational-radiation–driven **inspiral**; from their violently nonlinear **merger**, the most luminous event in the Universe; and from the **ringdown** phase as the two holes settle into a single, rotating black hole.

These signals encode the masses, spins, and orbital parameters of the binaries, as well as their distance and sky position. Recent breakthroughs in the numerical simulation of black-hole mergers make it possible to compare the measured waves with theoretical models, providing the first detailed **test of strong-field general relativity**.

Indeed, LISA will infer black-hole parameters from tens to hundreds of coalescences, shedding light on the formation and coevolution of galaxies and their nuclear black holes, and testing the hypothesis of galaxy and black-hole growth by **hierarchical mergers** and accretion. Did the first massive black holes arise from the collapse of supermassive stars, or of heavier gas discs? Did black holes grow mostly by accretion, or by mergers? LISA will provide new clues.

LISA will also measure **absolutely calibrated luminosity distances** to the binaries, with precisions ~1% for close systems in the absence of lensing. If a few host galaxies can be identified from optical counterparts in the < 10 deg^2 LISA sky-position error boxes, and their redshifts determined, LISA will constrain the redshift–distance relation, calibrating the distance scale and Hubble constant an order of magnitude better than existing methods, with different systematics, since the main source of error is the weak lensing along the line of sight.



LISA will map spacetime around massive black holes by detecting the radiation of inspiraling compact stars

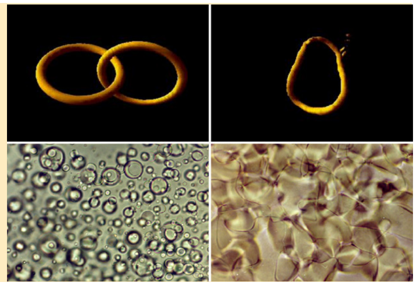
It will measure black-hole masses and spins to one part in 10^4, and test their Kerr nature to 0.1%

Compact stellar objects in galactic nuclei can enter a region of phase space where their further evolution is dominated by gravitational-wave emission; after a long inspiral, they are doomed to plunge into the central black hole.

The gravitational-wave signals from these **extreme mass-ratio inspirals** encode a detailed map of the warped spacetime that they traverse, so LISA will be able to verify whether galactic centers host rotating black holes, or other exotic objects. These signals will also yield a census of the **masses and spins of galactic black holes**, and of the species of compact objects in nuclei.

LISA will search for the gravitational-wave signatures of the early Universe and for new forms of "dark physics"

It could detect the stochastic signal from first-order phase transitions, as well as the backgrounds, bursts, and periodic signals from cosmic superstring loops



The LISA frequency band spans the **Terascale frontier** of the early Universe, where phase transitions of new forces of nature or extra dimensions of space may have caused explosive bubble growth and efficient gravitational-wave production. LISA can detect a **stochastic background** from such events, emitted at times between 3×10^{-18} and 3×10^{-10} s after the Big Bang, probing new physics in complement to particle accelerators. LISA will also be sensitive to the radiation from topological defects such as the cosmic superstrings predicted in some versions of string theory.